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# POWER SUPPLIES UNLIMITED

NJE CORPORATION Kenilworth, New Jersey

# INSTRUCTION MANUAL

for

MODELS

~~TR 18-3~~ and TR 36-2

SOLID STATE TRANSISTORIZED

REGULATED POWER SUPPLIES

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Kenilworth, New Jersey
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# SECTION I

## SPECIFICATION AND DESCRIPTION

1-1. NJE Solid State "TR" Regulated Power Supplies meet the conservative ratings given below:

| | | |
|---|---|---|
| Input: | | 115 volts RMS ±10%, 60 cycles ±5 cycles, single phase. Approximately 1.8 amperes at 75% power factor at full load. |
| Output Voltage: | TR-18-3 | 0-18 volts continuously adjustable by a front panel control knob. Fifty millivolt resolution. A ten-turn potentiometer can be furnished on special request to provide a 3-millivolt resolution. |
| | TR 36-2 | 0-36 volts continuously adjustable by a front panel control knob. Seventy-five millivolts resolution. A ten-turn potentiometer can be furnished on special request to provide 5-millivolt resolution. |
| Output Current: | TR 18-3 | Three amperes over most of the 0-18-volt range. Must be derated slightly at either end of the voltage range, as determined by the input line voltage. See Chart. |
| | TR 36-2 | Two amperes over most of the 0-36 volt range. Must be derated slightly at either end of the voltage range as determined by the input line voltage. See chart. |
| Static Regulation: | Load: | ±0.03% or ±1 millivolt (whichever is greater) for slow variations from no load to full load, at constant line voltage. |
| | Line: | ±0.05% or ±2 millivolts (whichever is greater) for slow line changes of ±10% at constant load. |
| Dynamic Regulation: | TR 18-3 | Load: 180 millivolts for a 2-ampere step having a 10-microsecond rise time. |
| | | Line: ±0.05% or ±2 millivolts (whichever is greater) for step line changes of ±10%. |

TR 36-2 Load: 90 millivolts for a 1-ampere step having a 10-microsecond rise time.

Line: ±0.05% or ±2 millivolts (whichever is greater) for step line changes of ±10%.

**Ripple:** Total of hum and noise will not exceed 2 millivolts peak to peak.

**Recovery Time:** Less than 50 microseconds for a full load step.

**Duty:** Rated for continuous duty at ambient temperatures from 0° C to 35° C. Current rating must be reduced by 20% for every 10° C rise above 35° C.

**Remote Sensing:** Sensing terminals, separate from the output terminals, are provided in order that the unit may "sense", and regulate against, the voltage at the load rather than the voltage at the output terminals.

**Remote Programming:** TR 18-3 This circuit has a sensitivity of about 140 ohms per volt. "Remote Program" terminals are provided. By varying the remote resistance in series with these two terminals, the output voltage may be accurately controlled from 0-18 volts.

TR 36-2 This circuit has a sensitivity of about 140 ohms per volt. "Remote Program" terminals are provided. By varying the remote resistance in series with these two terminals, the output voltage may be accurately controlled from 0-36 volts.

**Series-Parallel (Dualling) Operation:** TR 18-3 Two units may be operated in series to provide 0-36 volts, 0-3 amperes over most of the voltage range, or in parallel to provide 0-18 volts, 0-6 amperes over most of the voltage range. See Chart.

TR 36-2 Two units may be operated in series to provide 0-72 volts, 0-3 amperes over most of the voltage range, or in parallel to provide 0-36 volts, 0-4 amperes over most of the voltage range. See chart.

**Protection:** Load and power supply protection for a momentary overload condition is accomplished by an electronic current-limiting circuit.

If the overload condition is sustained, automatic-removal of the load is effected by the thermal characteristics of a slow-blow type fuse.

On short circuit, the current will be electronically limited for an indefinite period to 3 amperes for TR 18-3 and 2 amperes for TR 36-2.

**Polarity:** The output can be floated up to 500 volts peak above or below ground. Either polarity may be grounded to chassis.

**Meters:** Two 3" rectangular 2% meters are furnished installed on the front panel.

| | TR-18-3 | TR 36-2 |
|---|---|---|
| Ammeter: | 0-3 amperes | 0-3 amperes |
| Voltmeter: | 0-20 volts | 0-50 volts |

**Internal Impedance:** 0.1 ohm maximum, measured from DC to 20 KC.

**Mounting:** Suitable for laboratory bench use, or for 19" rack mounting by means of rack adapter panels.

Model RP1 - 5-1/4" high, 19" wide, with cutout for one unit.

Model RP1A- Same as Model RP1 except that cutout is offset to leave right half of panel blank.

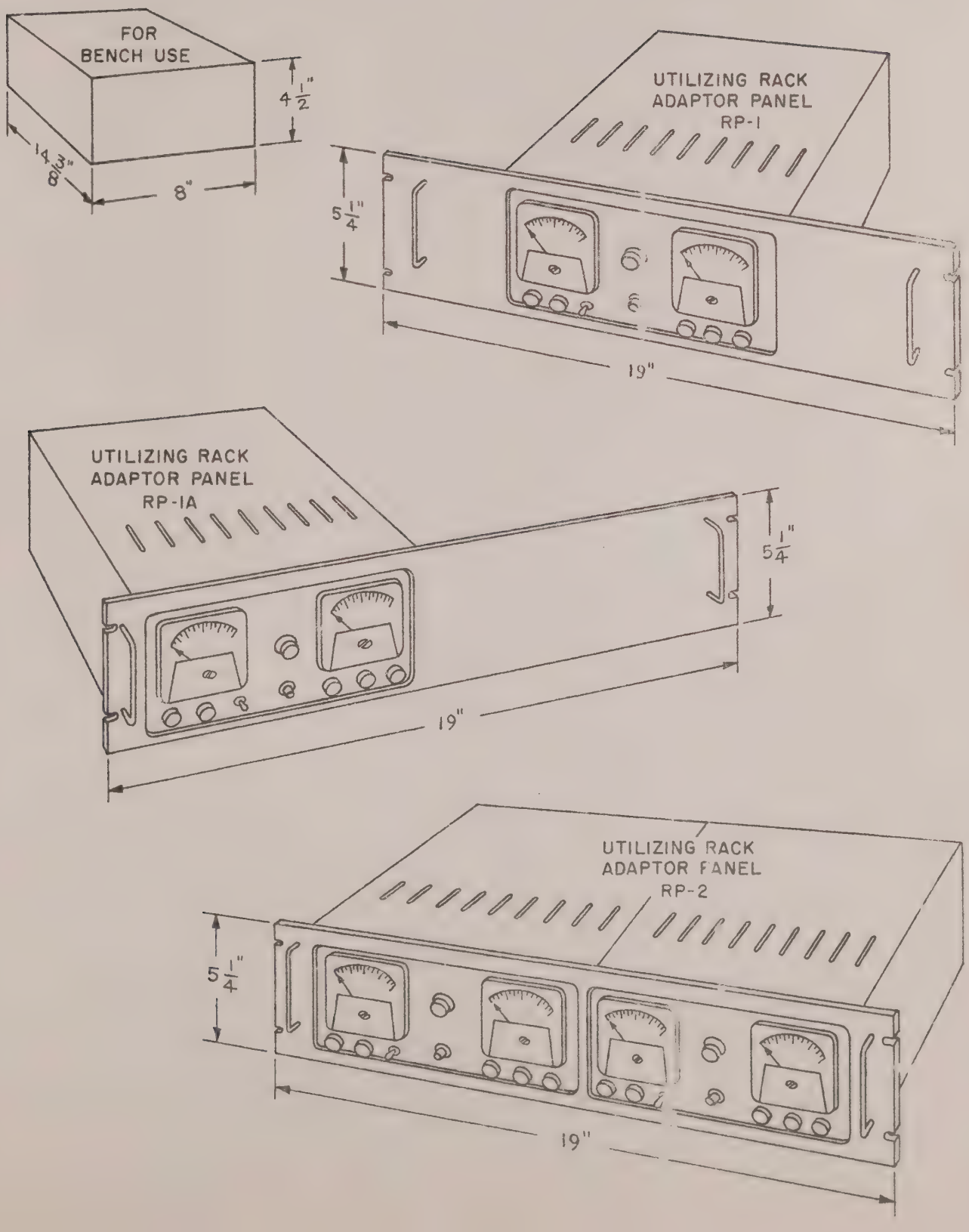
Model RP2- 5-1/4" high, 19" wide, with cut-outs for two units.

**Dimensions:** 4-1/2" high, 8" wide, 14" deep.

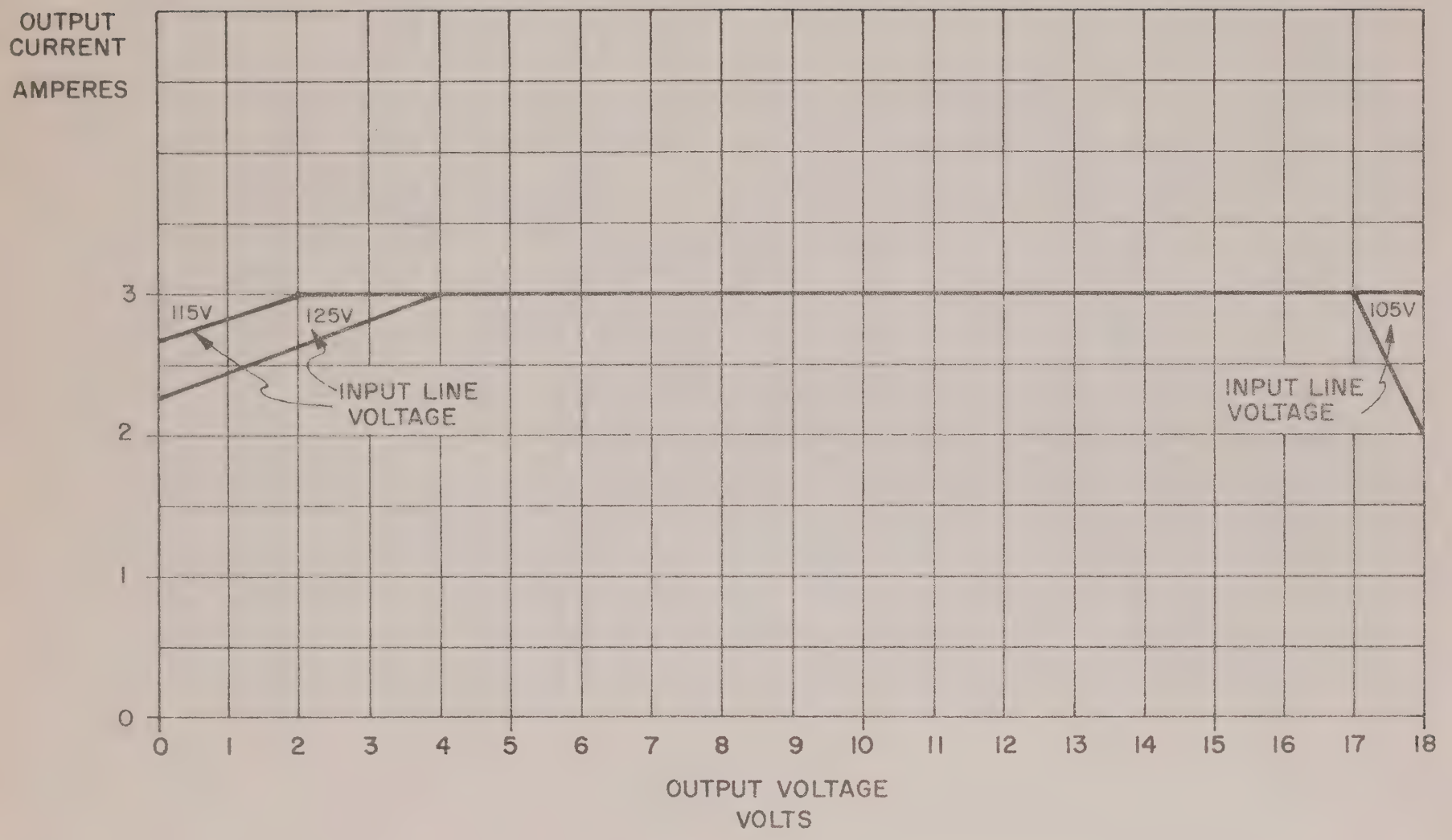
**Panel Elements:**

"On-off" switch
AC line fuse in extractor post
"On" pilot light (red)
DC fuse in extractor post
Output voltage control knob
Output voltmeter
Output ammeter
Output terminals- Positive- red
Negative- black
Ground - black

| | |
|---|---|
| Termination: | A barrier type terminal strip at the rear of the unit provides terminals for input, output, remote sensing, remote programming, dualling and ground. |
| Finish: | Panel finish is gray hammertone enamel. |
| Weight, net: | 15 pounds. |
| Weight, shipping: | 20 pounds. |
| General Design: | Completely solid state. Silicon power rectifiers, silicon zener diode references, germanium control and power transistors, all well derated, characterize the quality and dependability of this supply. Ninety (90) percent of the wiring is accomplished with printed circuitry. |


FOR
BENCH USE
4 1/2"
14 3/4"
8"
UTILIZING RACK
ADAPTOR PANEL
RP-1
5 1/4"
19"
UTILIZING RACK
ADAPTOR PANEL
RP-1A
5 1/4"
19"
UTILIZING RACK
ADAPTOR PANEL
RP-2
5 1/4"
19"

# TR 18-3

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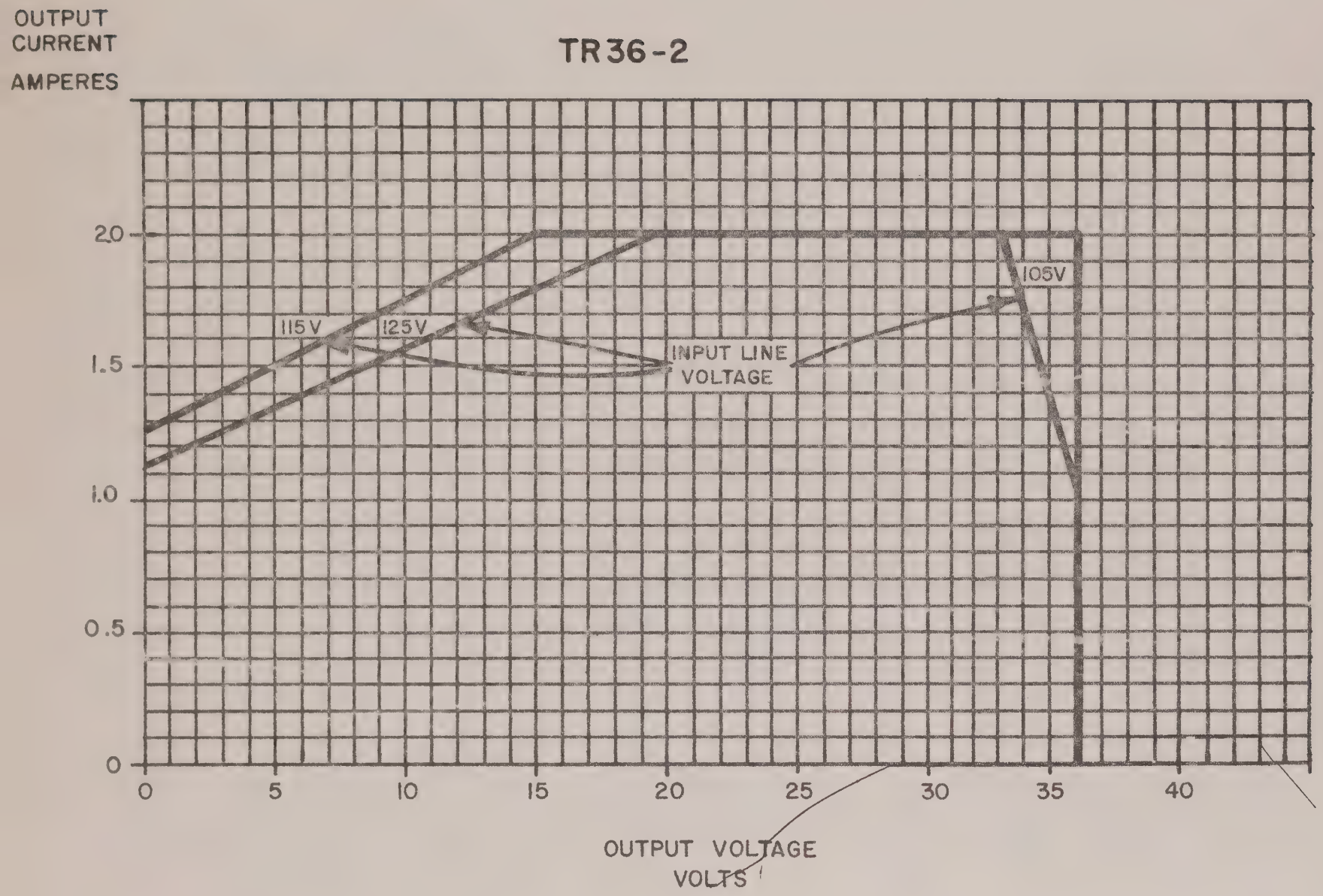
# TR36-2


OUTPUT CURRENT AMPERES
2.0
1.5
1.0
0.5
0
0
5
10
15
20
25
30
35
40
115V
125V
105V
INPUT LINE VOLTAGE
OUTPUT VOLTAGE VOLTS

## SECTION II

## INSTALLATION AND OPERATION

2-1. UNPACKING. The power supply is shipped in a cardboard carton which is floated on sufficient insulation in a heavy-duty shipping carton. Aside from normal precaution against damage to the unit in opening the cartons and removing the unit, no special procedures are required. The literature packed with the supply should be removed and held for reference in operating the equipment.

2-2 INSTALLATION. The supply can be mounted in any convenient location for bench use, and requires no adjustment or modification for such application. If the unit is to be installed in a housing, it is recommended that rack panel adapters be obtained from NJE. See Figure I. The panel is notched for standard rack mounting.

2-3 LOAD CONNECTIONS. When the unit has been properly placed in position, or mounted in its rack and secured in place by the panel screws, refer to the schematic diagram and make the following connections:

1. Using No. 16 AWG wire, connect either the positive or negative DC output terminal of the supply (according to the polarity desired) directly to the chassis ground terminal, at the barrier strip on the rear of the chassis, or at the front panel connector, and connect the ground terminal to the system ground. If it is necessary that the power supply circuit float above or below ground, the output terminal should be connected to the chassis ground terminal by a 0.1 microfarad 600 W VDC capacitor in place of the direct connection. Use of the by-pass capacitor will improve the stability of the circuit in the ungrounded condition, and reduce the effect of external interference and hum.

2. Connect the positive and negative output terminals to the corresponding terminals of the external load, using No. 16 AWG wire.

2-4. REMOTE SENSING. Remove jumpers from between terminals TB1-4 and TB1-5, and terminals TB1-7 and TB1-8 on the barrier strip at the rear of the chassis. Connect the positive sensing terminal TB1-8 to the positive terminal of the remote load, and the negative sensing terminal TB1-4 to the negative terminal of the remote load. Use No. 20 AWG shielded wire for this (preferably a twisted pair mounted in a common shield), and connect the shield to the chassis ground terminal. Do not connect the shield to any other point; make sure that the shield is insulated from all other wires, shields, frames, chassis and grounds.

Connect the de-activated input line (115 volts nominal, 60 cycles, single phase) to the AC input terminals on the barrier strip, using No. 16 AWG wire.

2-5. REMOTE PROGRAMMING. Remove the jumper from between terminals TB1-11 and TB1-12. Connect a remote resistor (fixed or adjustable) in series with these terminals. The output voltage will be accurately controlled by adjusting either the local "Output Adjust" control knob, potentiometer R16, or the remote resistor. The output voltage will be proportional to the sum of the resistance of R16 and the remote resistor, at a rate equal to approximately one (1) volt for each 140 ohms in the circuit. To obtain output voltage control over the entire range, from zero (0) to maximum rated voltage, the loca "Output Adjust" control knob must be turned counterclockwise to the minimum position.

CAUTION

Do not exceed the maximum rated output voltage by inserting too much resistance in the "Remote Program" circuit. An open circuit between terminals TB1-11 and TB1-12 will cause the voltage to rise to approximately 150% of rated maximum, at no load.

2-6. DUALLING, SERIES CONNECTION. See Figure 2 below. Two identical units may have their outputs connected in series to provide up to twice the rated output voltage. When remote sensing is employed, connect wires as indicated in Figure 2. For local sensing, leave jumpers connected between TB1-7 and TB1-8, and TB1-4 and TB1-5 of Unit No. 1, and leave jumper between terminals TB1-4 and TB1-5 of Unit No. 2 connected. Since there will be some voltage drop in the wire connecting TB1-5 of Unit No. 1, and TB1-7 of Unit No. 2, it is recommended that TB1-8 (Positive Sensing) of Unit No. 2 be connected to TB1-4 of Unit No. 1 in order to sense the drop and compensate for it.

2.7 DUALLING, PARALLEL CONNECTION. See Figure 2 below. Two iden - tical units may have their outputs connected in parallel to provide up to twice the rated output current. When remote sensing is employed, connect wires as indicated in Figure 3. Keep leads between units as short as possible, or in lieu of this, use heavier wires. For local sensing, use same connections as indicated in Figure 3, except the sensing leads of Unit No. 2 (the Master Unit) TB1-4 and TB1-8 should be connected directly to the output terminals of Unit No. 1 (the Slave Unit) terminals TB1-5 and TB1-7, respectively. If connected properly, the current unbalance, as indicated by the individual ammeters, should not exceed 10%.

2-8. OPERATION. Set the AC control switch on the front panel in OFF (open) position and energize the AC input line. Place the AC control switch in the ON position. The red indicator on the front panel should light.

Dualing - Series, with Remote Sensing

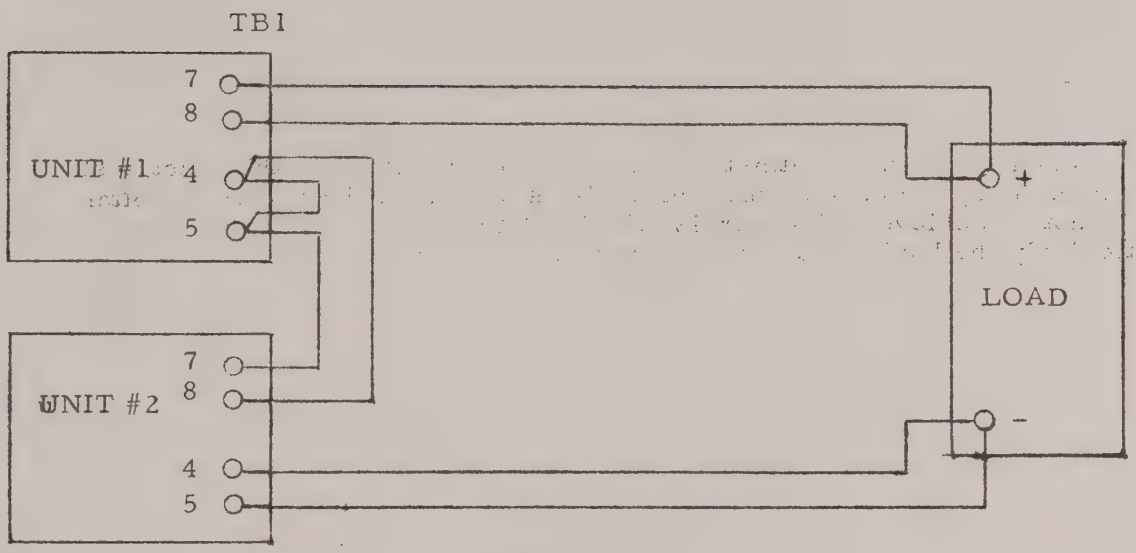



Figure 2

Dualing - Parallel, with Remote Sensing

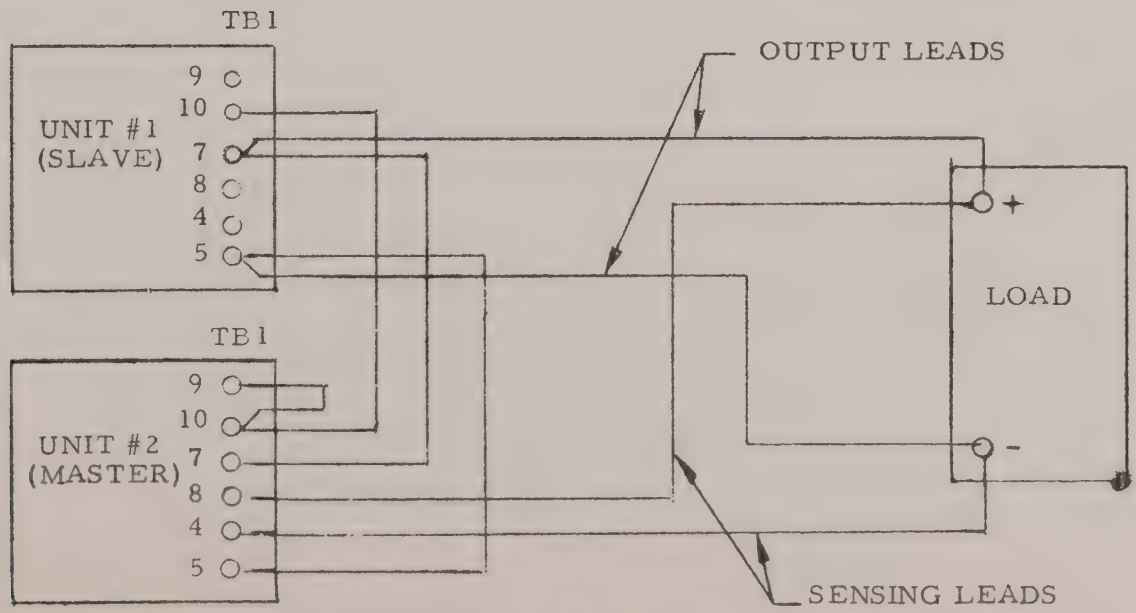



Figure 3

Observing the panel voltmeter, adjust the load voltage to the exact desired value, using the control knob on the front panel. If the required voltage cannot be achieved, de-energize the input line and check connections, particularly the load and sensing leads and their terminals.

# SECTION III

## PRINCIPLES OF OPERATION

3-1. GENERAL. A simplified block diagram, illustrating the basic elements of the circuit and the signal flow, is shown in Figure 4. The AC line voltage is converted to a practical value by the power transformer and rectified by a full-wave diode rectifier. A capacitor-input filter smooths the pulsating DC output of the rectifier, providing a low-ripple, unregulated DC voltage to the output regulator. The output voltage furnished to the load by the regulator is monitored by a feedback amplifier which compares this voltage with a stabilized reference voltage and amplifies the difference between the two voltages. The output of the amplifier is used to control the regulator in such a way that it counteracts any change in the DC output voltage, thereby furnishing an essentially constant voltage to the external load, despite variations in input line voltage or output load current.

3-2. DETAILED CIRCUIT DESCRIPTION. Circuit references in the following material apply to the schematic diagram at the back of the manual. This diagram shows electrical relationships, without regard to actual physical location of the components, and is laid out in an arrangement approximately the same as that in the block diagram, Figure 4.

3-3. The power supply is energized by connecting 115 volts (nominal), 60 cycles, single-phase, to the input terminals, and closing switch S1, attested by the lighting of pilot lamp DS1.

3-4. The power transformer T1 converts the primary line voltage to an appropriate value on its main secondary winding for operation of the power circuit. The transformer output voltage is rectified by diodes CR1, CR2, providing a pulsating DC output which is smoothed by the capacitor-input filter C1 and applied through a regulating transistor assembly Q3-Q5 to the external load. Capacitor C2 provides additional filtering of the output, and reduces the internal impedance of the supply for high-frequency load variations.

3-5. The output voltage on the auxiliary secondary of transformer T1 is rectified by diodes CR3- CR6, and filtered by capacitors C3-C4 to provide positive and negative operating potentials for the feedback amplifier. Zener diode CR7 in conjunction with its load resistor R7 provides a regulated +5.6 volts DC, while diode CR8 with resistor R10 provides -18 volts DC (measured with respect to the neutral bus terminal 7 of the printed board). These zener diodes function in a manner analogous to that of a gaseous voltage retulator tube, providing a relatively constant output voltage across their terminals despite variations in the conducted current.

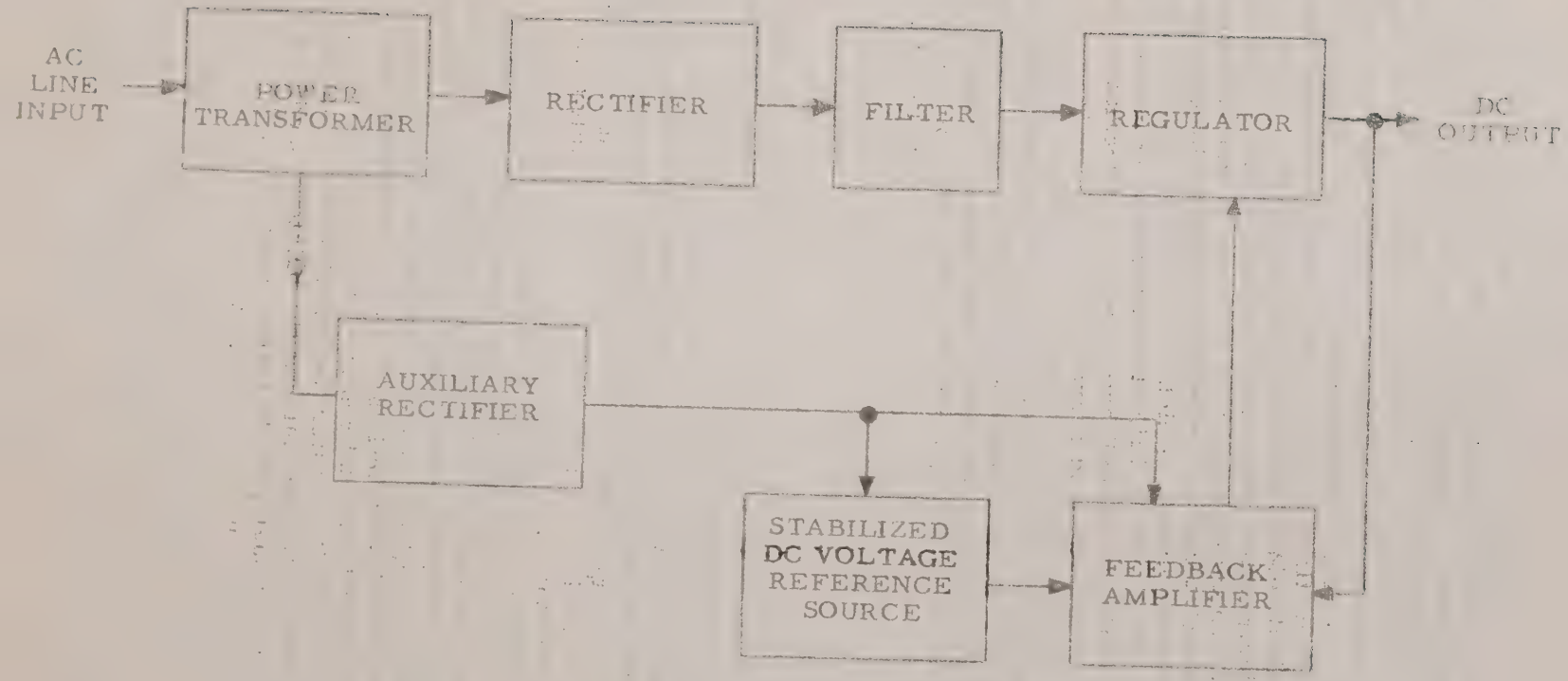



Figure 4. Regulated DC Power Supply, Simplified Block Diagram

3-6. The feedback amplifier consists of two stages of balanced amplification, assuring minimum sensitivity to fluctuations in ambient temperature or operating voltages. The input signal for the amplifier is derived from a sensing voltage divider connected across the output of the supply. This divider consists of resistors R18 and R17 in the amplifier, and adjustable resistor R16 on the front panel. The resistance value of R16 and the remote programming resistor in series determines the operating value of the DC output voltage of the supply in a manner which will be explained below.

3-7. The negative end of the sensing voltage divider (negative end of resistor R18) is returned to the negative output of the supply through zener diode CR9, the neutral bus terminal of the amplifier, and the negative sensing lead. The diode, in conjunction with its load resistor R15, provides a highly stable potential of 5.6 volts DC for use as a comparison voltage by the input stage of Q8- Q9 of the feedback amplifier. When the output of the power supply (measured at the load) is precisely at its selected nominal value, the voltage at the base of transistor Q9 (derived from the sensing voltage divider) is at the same level as the base of transistor Q8, and the input stage is in balance. Under this condtion, any tendency of the load voltage to vary in either direction will unbalance the amplifier, resulting in corrective action which compensates for the impending change, and holds the load voltage at its established value, as explained below.

3-8. Transistors Q8 and Q9 are PNP type units, operated in common-emitter mode, and connected as a balanced differential amplifier. Their outputs, taken across load resistors R13 and R14, are direct-coupled to the bases of the succeeding differential amplifier stage Q6-Q7, which consists of two NPN transistors operated in common-emitter mode. The output of Q6, from its load resistor R8, is tied directly to the base of the driver transistor Q1 in the regulator element.

3-9. Regulation of the DC output is performed by transistor assembly Q3-Q5 connected in series with the negative output. As directed by the output of the feedback amplifier, this transistor assembly adjusts its conductivity to continuously absorb the difference between the unregulated DC supply voltage and the selected DC output voltage, regardless of input line conditions or the load current drawn. Circuit protection is provided by resistor divider R20, R21 and R22 in conjunction with transistor Q2. The divider senses the drop across R2 which is proportional to the output current, and provides a signal on the base of Q2. Should excessive current flow through the pass transistors Q3-Q5, this excessive current will appear as a larger than normal drop across R2, which in turn is applied through the divider to the base of Q2. Q2 then becomes conductive, clamping the Q1 base to emitter voltage thus preventing any further current increase. R20 is factory adjusted to limit the maximum current to a safe value and should not be disturbed. Since the regulating transistors exhibit some leakage at cutoff conditions, a bleeder resistor R6 is used to provide a path for this current, so that the circuit will stay in regulation at zero load. Resistor R5 serves the same purpose for the driver transistor Q1.

3-10 The sequence of corrective action around the feedback loop is as follows: The input to transistor Q8 is the zero reference level--in this case the voltage at the negative terminal of the load. The input to transistor Q9 is the difference between the voltage across diode CR9 (the reference voltage) and the voltage on the sensing voltage divider at terminal 9 of the printed circuit board. When the DC load voltage is at the selected value, the voltage at the divider and the voltage across diode CR9 are equal, though of opposite polarity, and cancel each other out, so that the base of Q9 is at the same potential as the base of Q8 and the outputs of the two transistors are balanced. When the load voltage tends to deviate from the selected value in either direction, due to a change in load current or in input line voltage, this causes the voltage on the sensing divider to differ from the voltage across the reference diode CR9, and the difference (or "error") voltage unbalances the amplifier stage Q8-Q9. This difference appears in amplified form in the output of this stage, and is further amplified by the subsequent amplifier stage before being applied to the driver transistor Q1. The output of the driver transistor causes the regulating transistor assembly Q3-Q5 to increase or decrease its conductivity in accordance with the error signal so that its overall emitter-collector voltage drop absorbs the impending variation in load voltage, maintaining an essentially constant value of voltage across the load terminals. Capacitor C5 assists the amplifier in responding to rapid changes in load voltage by bypassing a portion of the sensing circuit. The more rapid the change, the greater is the initial transfer of voltage direct to the input of the amplifier, enabling it to anticipate any radical load variation before the excursion becomes significant.

3-11. The sensitivity and speed of response of the corrective feedback circuit is such that the above-described action occurs almost instantaneously, and the actual excursion of the load voltage is held to a very small value. The circuit is a true proportional regulator, and must allow a small but finite "error" to exist between the required and actual regulated voltage, so that this error, however small, can generate the correction signal. By proper circuit design, the error is held to a value which remains within the specified regulation allowance of the power supply.

3-12. When resistors R16 and/or the remote programming resistors are readjusted to produce a difference value of output voltage, the circuit makes a correction similar to that described above. Altering the resistance in the sensing voltage divider unbalances the input stage of the feedback amplifier, which then causes the circuit to produce a new value of voltage such that the drop across resistors R17-18 again equals the drop across diode CR9. Reducing the value of the remote programming resistor, for example, momentarily increases the drop across R17-R18 (assuming a constant value of the output voltage). However, this unbalanced condition at the amplifier input causes the DC output voltage to decrease until the drop across R17-R18 again equals the drop across CR9 and the circuit stabilizes at this new operating point, establishing a lower value of DC output voltage.

3-13. Resistor R18 in the amplifier is provided to permit compensation for manufacturing tolerances in diode CR9, its load resistor R15, and resistor R17.

resistor R17. (This resistor is adjusted at the factory and locked.) If any of these components is replaced, check to see that full rated output voltage of the supply is obtainable at full load, with voltage control at maximum clockwise position, with line voltage of 105 volts. If not, readjust R18 to provide full voltage under these conditions.

# SECTION IV
# MAINTENANCE

4-1. GENERAL. This section is arranged in the form of a trouble-shooting chart, with symptoms listed approximately in accord with the frequency of occurrance. Possible causes for each, and their remedies, are listed in logical succession beginning with the most common, to facilitate rapid location and isolation of a defective element.

4-2. SPARE MODULES. Where practical, it is recommended that one or more spare regulator assemblies be kept available for use in maintenance. This will reduce down-time to a minimum, and permit easy testing by direct substitution, making it possible to repair a defective module at some convenient time and avoid prolonged interruption of operation.

4-3. MALFUNCTIONS. The various ways in which DC power supplies can deviate from normal operation are listed below. Each condition is treated separately in the charts that follow. References are to the schematic diagram at the rear of the manual.

| MALFUNCTION | TYPICAL MAGNITUDE |
|---|---|
| 1. No output voltage at any control setting. | Zero or negative DC output voltage. |
| 2. Low output voltage. | Maximum output voltage obtainable at no load is less than minimum rating. |
| 3. High output voltage. | Minimum output voltage obtainable at no load is more than minimum rating. |
| 4. Failure to regulate. | Output voltage drops 5% or more when load is applied, or varies ±2% or more under a ±10% variation in line voltage. |
| 5. Poor regulation. | Regulation better than above, but not within specification. |
| 6. Excessive ripple. | |
| A. With good regulation. | RMS ripple exceeds specification, but regulation is within specification. |
| B. With poor regulation. | RMS ripple exceeds specification, and regulation exceeds specification. |

| MALFUNCTION | TYPICAL MAGNITUDE |
|---|---|
| 7. Instability. | |
| A. Random large excursions. | Outpus voltage "hops" intermittently by 5% or more, with constant load, and constant line voltage. |
| B. Gradual drift in one direction. | Output voltage changes by 1% or more per minute, after 15-minute warmup. |
| C. Excessive drift under heavy load only. | Output voltage changes by 1% or more per minute after a 15-minute warmup, but only after application of a heavy load. |
| 8. Inadequate transient suppression. | Failure to "zero-lag". Upon sudden application of a full load increase(within rating), output voltage dips sufficiently to cause a visible momentary deflection of the voltmeter needle. |
| 9. Oscillation. | |
| A. High frequency. | Under constant load, output voltage is modulated by sawtooth or sine-wave with frequency of 200 cycles or more per second. |
| B. Low frequency (motorboating). | At constant load, output voltage exhibits relaxation modulation at or below 30 cycles per second. |

4-4. NO OUTPUT VOLTAGE.

| SYMPTOM | POSSIBLE CAUSE | REMEDY |
|---|---|---|
| A. Pilot light DS1 not lit. | 1. No line power, or defective input connection. | 1. Check power source, lines & connections. |
| | 2. Input fuse F1 blown. | 2. Replace fuse. If fuse blows repeatedly, do not overfuse. Check subsequent circuits for short overload. |
| B. Pilot light DS1 lit. | 1. Output fuse F2 blowh. | 1. Replace fuse (see above comment). |
| | 2. Dead short on output circuit. | |

| SYMPTOM | POSSIBLE CAUSE | REMEDY |
|---|---|---|
| | a. External | a. Check load circuit. |
| | b. Internal | b. Shorted filter capacitor C2, or wiring short. |
| C. No unregulated DC across C1. | 1. Defective rectifier CR1-2. | 1. Test for back resistance of individual diodes. Replace if not greater than several thousand ohms. |
| | 2. Main secondary of power transformer T1 open. | 2. Replace transformer. |
| | 3. Auxiliary secondary of transformer T1 open. | 3. Replace transformer. |
| D. Unregulated DC present at C1 in expected magnitude (25 to 50% higher than DC output voltage, at nominal line voltage, without load). | 1. Entire unregulated DC voltage absorbed by regulator transistors (voltage across C1 equal to voltage across Q3), caused by short or excessive leakage between base of driver transistor Q1 and any positive voltage. (For example: if positive output is operated at chassis ground & a wiring short or excessive leakage exists between base of Q1 and chassis). | 1. Inspect for short. Isolate driver transistor from heat sink and chassis, and operate unit for brief interval. If this restores normal operation, replace driver insulation, and/or driver itself as necessary. |
| | 2. Amplifier or sensing circuit defective. | 2. Check by momentarily connecting driver base Q1 to negative output terminal. If DC output is restored, amplifier or sensing circuit is at fault. See end of this section for amplifier check. |
| | 3. Defective pass transistors and/or drivers. | 3. Check by momentarily shorting pass transistors Q3, Q4 or Q5 at no load. Replace pass transistors (or their modules). |

| SYMPTOM | POSSIBLE CAUSE | REMEDY |
|---|---|---|
| | 4. Ammeter M1 open. | 4. Check by momentarily shorting meter terminals. Replace. |
| | 5. Resistor R1 open. | 5. Replace. |

4-5. LOW OUTPUT VOLTAGE.

| SYMPTOM | POSSIBLE CAUSE | REMEDY |
|---|---|---|
| A. Unregulated DC present at C1 in expected magnitude (25% to 50% higher than max. DC output voltage at nominal line voltage at no load). | 1. Excessive amount of unregulated DC voltage absorbed by regulator transistor (voltage across C1 equal to voltage across Q3), caused by excessive leakage between base of driver transistor Q1 and any positive voltage. | 1. Isolate driver transistor from heat sink and chassis, and operate unit for brief interval. If this restores normal operation, replace driver insulation and/or driver transistor. |
| | 2. Amplifier or sensing circuit defective. | 2. Check by momentarily connecting driver base Q1 to negative output terminal. If this restores DC output, check sensing voltage divider. See end of this section for amplifier check. |
| | 3. Rate sensing capacitor C5 has excessive leakage. | 3. Disconnect one terminal of capacitor. If this restores DC output, replace capacitor. |
| | 4. Defective pass transistor. | 4. Check by momentarily shorting pass transistors Q3, Q4 and Q5 at no load. Replace pass transistors or their modules. |
| | 5. Filter capacitor C1 | 5. Replace. |

| | | |
|---|---|---|
| | 6. Defective diode in rectifier CR1-2. | 6. Check for low back resistance in any diode, and replace as necessary. |
| | 7. Defective current limiting diode CR10. | 7. Check by momentarily disconnecting one terminal of diode. |

## 4-6. HIGH OUTPUT VOLTAGE.

| SYMPTOM | POSSIBLE CAUSE | REMEDY |
|---|---|---|
| 1. Output voltage adjust knob has little control over DC output. | 1. External sensing circuit improperly connected. Internal sensing voltage divider or wiring open. | 1. With power off, check continuity of sensing leads, remote programming leads, and internal sensing circuit from positive output terminals to amplifier input Q8 base, and from negative output terminals to neutral bus of amplifier. |
| 2. Output control effective. Driver base Q1 negative with respect to negative output terminal. | 2. (a) Bleeder resistors R6 open, or driver emitter bleed circuit is open (R5) | 2 (a) Check by applying full load. If this restores normal operation, check for open resistor or connection. |
| | (b) Defective amplifier. | (b) See amplifier check at end of this section. |
| | (c) Defective amplifier power supply. | (c) Check voltage across filter capacitor (C3) as shown on schematic diagram. If correct, check resistors R7, R10 for open. If incorrect, check the capacitors, diodes CR3-CR6, and auxiliary secondary winding of transformer. |
| 3. Driver base (Q1) positive with respect to negative output terminal. | 3. Defective driver and/or pass transistor. | 3. Check for shorted transistor. |

## 4-7. FAILURE TO REGULATE.

| SYMPTOM | POSSIBLE CAUSE | REMEDY |
|---|---|---|
| 1. Load regulation is 5% or more, line regulation 2% or more. | 1. (a) Defective amplifier. | 1. (a) See amplifier check at end of this section. |
| | (b) Defective amplifier power supply. | (b) Check voltage values of filter capacitors C3, C4. If incorrect, check the capacitor, diodes CR3-CR6, and auxiliary secondary winding of transformer. If correct, check resistors R7, R10. |
| | (c) Very low performance. | (c) Check for equal voltages across resistors in series with emitters of power transistors, to detect defective transistor. Check drivers in a transistor test set, or by substitution. |

## 4-8. POOR REGULATION

| SYMPTOM | POSSIBLE CAUSE | REMEDY |
|---|---|---|
| 1. Load regulation less than 5%, but not within specifications. | 1. Excessive resistance in output fuse F2, fuseholder, or output connection. | 1. Check output connections for loose or corroded terminals. Check fuse and holder by operating the unit with a temporary jumper shorting the fuseholder. |
| | 2. External sensing circuit open. | 2. Check by operating unit with sensing terminals temporarily jumpered to the local output terminals (observe correct polarity). |
| | 3. Low gain amplifier. | 3. See amplifier check at rear of this section. |
| | 4. Low beta in driver or power transistor | 4. Check by substitution or in transistor tester. Beta of 20 or more is acceptable. |

4-9. EXCESSIVE RIPPLE.

| SYMPTOM | POSSIBLE CAUSE | REMEDY |
|---|---|---|
| 1. Output regulation is within specifications. | 1. (a) Circuit not bypassed to ground. | 1. (a) One output terminal of the supply should be connected to chassis ground whenever practical, either directly or through a 0.1 mfd. capacitor or appropriate voltage rating. |
| | (b) Filter Capacitor C1, C3, or C4 open, or defective. | (b) Replace. |
| | (c) Rate-sensing capacitor C5 open or of low value. | (c) Replace. |
| | (d) Hum pick-up in external sensing leads. | (d) Check by operating unit with sensing terminals temporarily jumpered to local output terminals. |
| | (e) Low-gain amplifier. | (e) See amplifier check at end of this section. |
| 2. Output regulation poor. | 2. (a) Low beta in power transistor or driver transistor. | 2. (a) Check by substitution or in transistor test set. Beta of 20 or more is acceptable. |
| | (b) Low-gain amplifier | (b) See amplifier check at the end of the section. |
| | (c) Defective amplifier power supply. | (c) Check diodes CR3-CR6, capacitor C3 for open, low value, or high leakage. Check diodes CR7, CR8 and resistors R7 & R10. |

4-10. INSTABILITY.

| SYMPTOM | POSSIBLE CAUSE | REMEDY |
|---|---|---|
| 1. Random large excursions of output voltage. | 1. Intermittent failure of component or intermittent short or open in circuit. | 1. Check primary power circuit by temporarily connecting base of driver transistor Q1 to |

| SYMPTOM | POSSIBLE CAUSE | REMEDY |
|---|---|---|
| | | negative output terminal. If instability persists, check for intermittent breakdown in rectifier CR1, CR2 or filter capacitor C1. Check for intermittent opens or shorts in unregulated DC circuit. Check driver and power transistors in tester, or by substitution. Check for intermittent opens or shorts, or defective component from C1 to output terminals. If instability disappears when Q1 base is shorted to negative output terminal, look for intermittent open or short, or intermittently defective components in (1) amplifier, (2) amplifier power supply, or (3) sensing voltage divider and external sensing circuit. Check amplifier connector for poor contact. Check rate-sensing capacitor C5. |
| 2. Gradual drift in one direction at any load, after a 15-minute warmup. | 2. (a) Defective amplifier. | 2. (a) See amplifier check at end of this section. |
| | (b) Output adjust potentiometer R16 unstable or defective. | (b) Replace. |
| | (c) Remote program resistor unstable or defective. | (c) Replace. |

## 4-11. INADEQUATE TRANSIENT RESPONSE.

NOTE: This condition should be checked by oscilloscope at the output terminals of the supply, with the sensing terminals temporarily jumpered to the corresponding output terminals. None of the load current should be permitted to flow through any portion of the oscilloscope leads or the sensing leads.

| SYMPTOM | POSSIBLE CAUSE | REMEDY |
|---|---|---|
| 1. Regulation and ripple are within specification, and external sensing circuit is properly and firmly connected. | 1. (a) By-pass capacitor C2 open, or very low value. | 1. (a) Replace. |
| | (b) Filter capacitor C1 low in value. | (b) Replace. |
| | Note: A brief transient during switching is normal. The measurement of the transient response may be complicated by inductive transients of 1 to 50 microsecond duration due to load inductance, etc., but since these are easily handled by means of local bypassing, they have no significance in determination of the transient response of the supply. | |

4-12. OSCILLATION.

| SYMPTOM | POSSIBLE CAUSE | REMEDY |
|---|---|---|
| 1. Under constant load, output voltage varies at a cyclic rate (sawtooth or sine wave) of 200 cycles or more per second. | 1. (a) Defective diodes CR7, CR8, or resistors R7, R10. | 1. (a) Replace. |
| | (b) By-pass capacitor C2 is open. | (b) Replace. |
| | (c) Rate sensing capacitor C5 or its circuit is open. | (c) Replace. |
| | (d) Suppressor capacitors C7 or C6 in amplifier are open or disconnected. | (d) Reconnect or replace. |
| 2. Under constant load, output voltage varies in "sawtooth" manner at a frequency of 30 cycles or less. | 2. (a) By-pass capacitor C2 is open. | 2. (a) Replace. |
| | (b) Suppressor capacitor C6 or C7 in amplifier is open. | (b) Replace. |
| | (c) Rate sensing capacitor C5 is open, or not connected. | (c) Replace, or reconnect. |

| SYMPTOM | POSSIBLE CAUSE | REMEDY |
|---|---|---|
| | (d) Excessive capacitance in external load circuit. | d. If load contains capacitance equal to or greater than by-pass capacitor C5, with low power factor, special precautions are necessary. Check with NJE Corp. Engineering Dept. |
| | (e) Excessive amplifier gain | e. If the Beta of one or more amplifier transistors is 150% or more of the manufacturer's bogie value, the increased gain which results (particularly at low ambient temperature) could result in this type of oscillation. Replacement of the transistor is required. |

4-13. REGULATION CHECK. Because of the inherently slight regulation exhibited by this power supply, it is impracticable to make a regulation check by observing a voltage measurement across the output terminals of the supply as the line or load is varied.

4-14. To accurately check the regulation, it is necessary to use an external source of DC voltage of approximately the same value as the power supply output, connected as shown in Figure 5. This DC bucking voltage can be either an electronic unit, or a group of batteries connected in series, furnishing a DC potential larger than the output voltage of the power supply under test. The voltmeter should have a full-scale range of 0 to 5 or 10 volts (5-0-5 with center zero, if available), since it will be used to measure only the difference between two almost equal voltages. The balance adjustment is used to bring the meter needle to approximately midscale before testing, so that the deviation above or below the normal output of the supply under test can be observed.

4-15. The dummy load is selected to draw full load current at the nominal output voltage of the supply. The difference between the voltmeter readings with the switch open and closed (allowing the needle to come to rest before reading), gives the static regulation in volts.

4-16. Dynamic regulation is measured by substituting a calibrated oscilloscope for the voltmeter, and measuring the maximum deflection as a dummy load of appropriate value is switched in and out of the circuit.

4-17. FEEDBACK AMPLIFIER CHECK. There are several methods which can be used in checking the performance and condition of the feedback amplifier.

Except for individually removing the transistors for a check by means of a transistor test set, and making continuity and resistance tests on the circuit and components, all methods require the amplifier to be energized with the proper potentials under the conditions found in the power supply for normal operation. For this reason, it is simplest to test the amplifier in position in the supply, first making certain that its DC power supply (transformer, rectifiers (diodes CR3-CR6), capacitor C3, C4, diodes CR7, CR8, and resistors R7, R10) is functioning properly. This can be quickly ascertained by checking the circuit voltages as indicated on the schematic diagram. Once this is done, the procedures given below can be used to check out the amplifier itself.

a. Voltage Check. The simplest and most rapid direct check of the amplifier is made by connecting a temporary jumper from the base of transistor Q8 to the base of transistor Q9, thereby balancing the amplifier input stage, and checking for balanced voltages on the two amplifier stages. Any obvious discrepancy will indicate a defective stage, and simple analysis will pinpoint the defective connection or component. Verification is then made by testing the component itself or repairing the connection.

b. Signal Tracing Check. Since there is an inherent amount of ripple at the input to the amplifier, this ripple signal can be used as a test signal for observing the amplifier performance with the aid of a test oscilloscope. (Ignore any spikes in the waveform. Use only the basic ripple signal when making amplitude calculations.) In the event that the ripple is too small for practical use, a small 60-cycle sine-wave voltage of convenient amplitude (less than 1/4 volt) can be injected into the amplifier, applying it across amplifier terminals 9 and 21 for convenience. Measurement of the ripple at the input to the amplifier, and at the output of each successive amplifier stage will provide an effective check for amplifier performance. The ripple amplitude measured across the bases (or input) of the second stage transistors Q6 and Q7 should be 20 to 40 times the amplitude at the input to the first stage. The ripple at the base of the next stage, should be 15 to 30 times the ripple at the input to the previous stage. Radical departure from this set of condtions will point up a defective component or connection, which can then be isolated by inspection and individual test.

c. Stability Check. A detailed check for improper drift and intermittent failure can be made by utilizing a test rig similar to that shown for precise regulation check in Figure 5. The voltage across the zener diode reference source CR9 is "bucked out" and monitored by a 0 to 1-volt (or smaller scale, if available) high impedance DC voltmeter. Drift or random instability will be readily visible in this test. Output voltages of the successive amplifier stages and regulating diodes CR 7 and CR8 can then be monitored in the same manner. When checking a given amplifier stage by this method, the output of the previous stage should be shorted, to prevent external voltage variations from reaching the stage under test. When installing a new transistor in place of one shown to be defective, the stability check should be repeated, to make certain that the trouble has been eliminated.

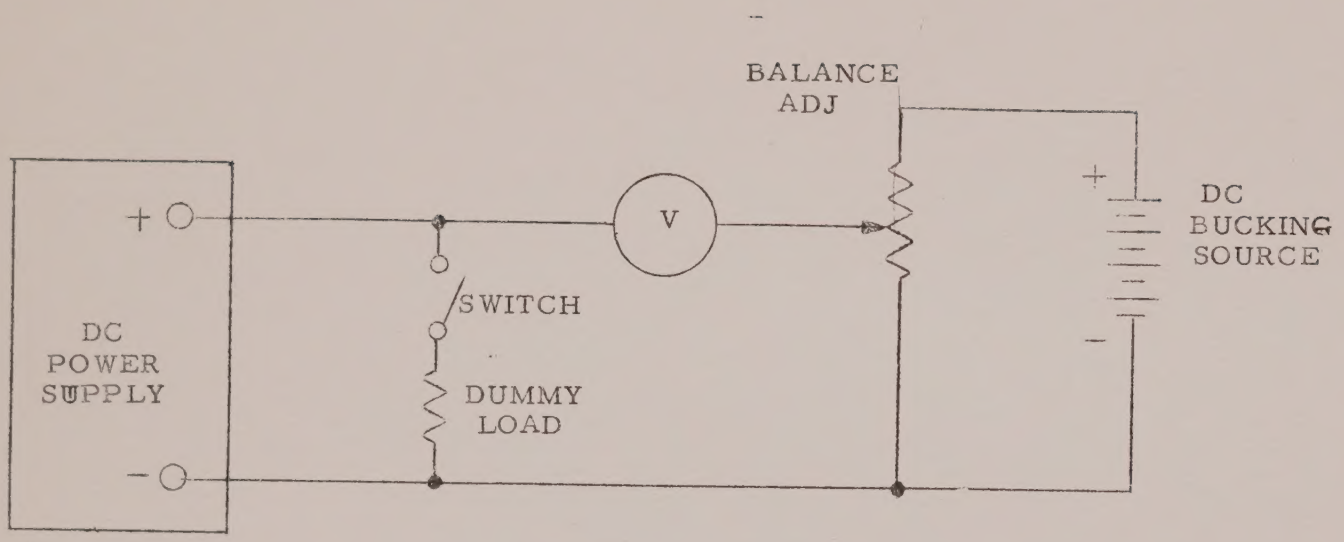



Figure 5. Precision Regulation Check

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